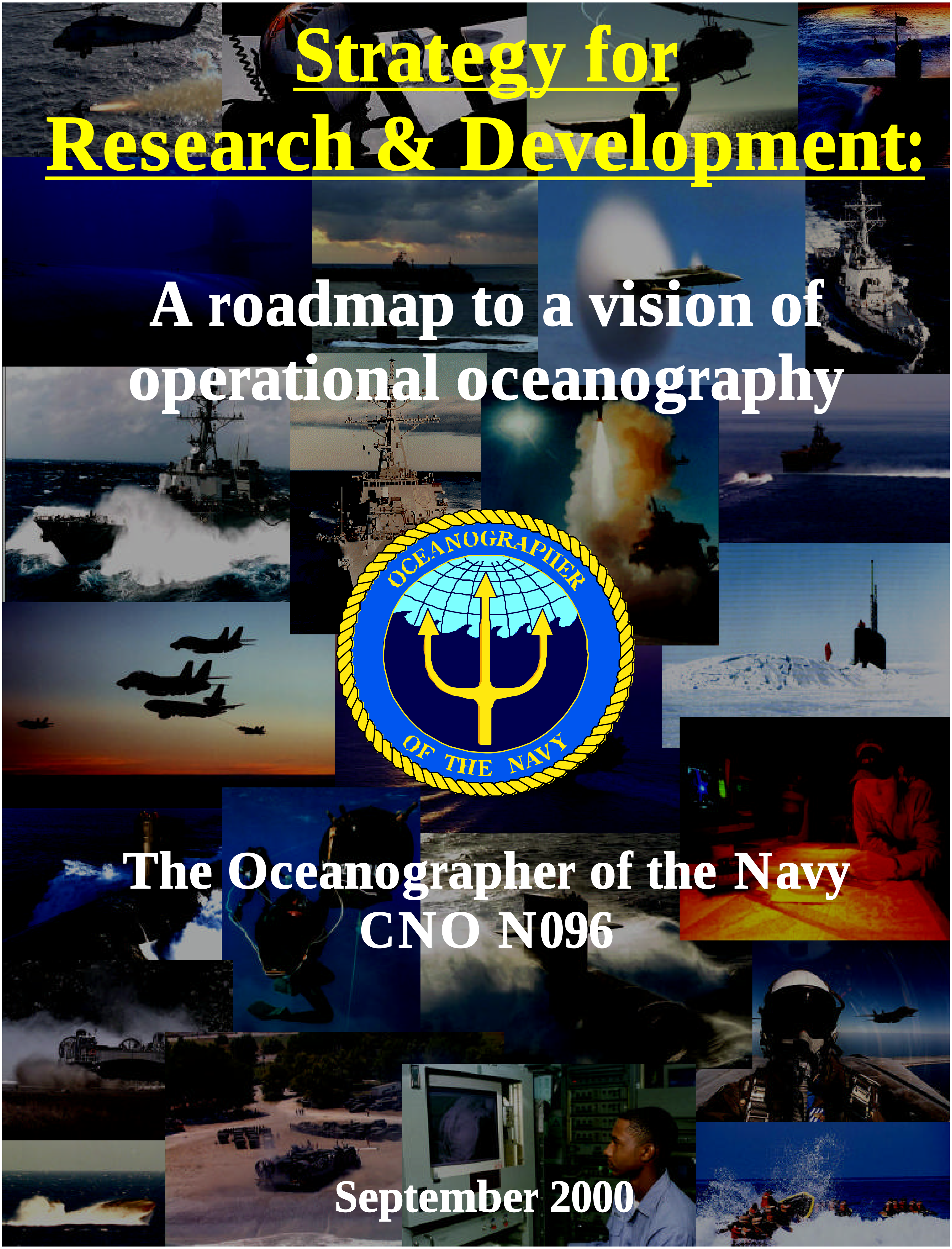

Strategy for Research & Development:

A roadmap to a vision of operational oceanography

The Oceanographer of the Navy
CNO N096

September 2000

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
2000 NAVY PENTAGON
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From: Chief of Naval Operations (N096)
To: Distribution

Subj: RESEARCH AND DEVELOPMENT (R&D) STRATEGY

Encl: (1) CNO N096 Strategy for Research and Development

1. Purpose. Provide a strategy for investment of N096 Meteorology and Oceanography (METOC) research and development resources. This builds on existing Naval Oceanography policy, and supports visions for 21st century warfare.

2. Summary. The CNO N096 R&D Strategy is attached as enclosure (1). This strategy for R&D in Naval METOC is defined by three fundamental principles:

a. All R&D sponsored by the Office of the Oceanographer of the Navy will be in direct support of the naval mission as established by formal naval doctrine and policy. This connectivity between R&D and operations is of paramount importance.

b. Well-established, mission-oriented criteria will be applied in determining our R&D investment priorities.

c. Our R&D investment will be expressed in terms of perdurable product lines, which are as interpretable for mission applications as they are for transition potential from science and technology.

3. Successful Naval operations require mastery of the complex maritime environment, anytime, anywhere, to maximize operational effectiveness and minimize impact on platforms, weapons, and sensors. This R&D Strategy will serve as a valuable tool in maintaining operational superiority for U.S. Naval Forces. My point of contact is Dr. Richard Spinrad, (202) 762-1697.

R. D. WEST
Rear Admiral, U.S. Navy
Oceanographer of the Navy

Subj: OCEANOGRAPHER OF THE NAVY R&D STRATEGY

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Executive Summary

This strategy for research and development (R&D) in naval meteorology and oceanography is defined by three fundamental principles:

1. All R&D sponsored by the Office of the Oceanographer of the Navy will be in direct support of the naval mission as established by formal naval doctrine and policy. This connectivity between R&D and operations is of paramount importance.
2. Well-established, mission-oriented criteria will be applied in determining our R&D investment priorities.
3. Our R&D investment will be expressed in terms of perdurable product lines, which are as interpretable for mission applications as they are for transition potential from science and technology.

The naval oceanographic community has a rich history of developing and transitioning products into operations, with a demonstrated positive impact on fleet performance. This strategy builds on this tradition and codifies the processes by which R&D investments will be identified and presented. The strategy is oriented around a vision for operational oceanography[1] and is designed to benefit from guidance received from within naval operational and research communities, as well as feedback from stakeholders outside of the Navy.

This strategy serves multiple purposes. Through regular application of the processes defined within, the strategy provides the following:

- Scope – the strategy, while aimed at optimizing the R&D investment, must also be translatable into impacts and recommendations for operations, training, manning, programming and planning.
- Customers – attention to customers, and the mechanisms for interacting with them, are part of the strategy.
- Processes – the strategy must define processes by which R&D investments can be identified, defended and assessed.
- Deliverables – the results of implementation of the strategy must be easily defined and consistent with the principles of the strategy.
- Metrics – the strategy must make use of and establish, where necessary, those measures of effectiveness required for critical review of the R&D investment.

This R&D strategy defines mission-critical research along specific and enduring 'product lines'. These are defined in terms that are immediately applicable to both the warfighter's mission and the researcher's capabilities. The combination of operational requirements and the ability to transition products of science and technology will define the emphasis of the research and development. The investment in operational oceanographic research and development must be prioritized by a spectrum of criteria. The strategy defined herein is enduring and adaptable to changing missions.

Successful implementation of this R&D strategy will clearly result in advantages for naval forces. Additionally, the naval oceanographic community will realize specific benefits. This strategy provides a tool for Navy to demonstrate visionary leadership in R&D for the broad community of operational oceanography. It will also

[1] "oceanography" as used throughout this document includes all related core competencies under the sponsorship of the Oceanographer of the Navy, including oceanography, meteorology, geospatial information and services, precise time, and astrometry.

provide a feedback mechanism, by identifying those focus areas for required capabilities in science and technology. Additionally, the strategy serves as a platform for developing mechanisms to continuously seek buy-in with other resource sponsors, and connectivity with the broader naval planning, programming and budgeting system. And, finally, the strategy should serve as a useful guide in daily project direction of the program managers working in naval oceanography.

I. Vision – *Where do we want to go?*

Operational oceanographic factors have had huge impacts on every modern naval action. Whether producing detailed descriptions of the waves, tides and currents for an amphibious mission, synthesizing a full three-dimensional depiction of the sound velocity profile for a theater anti-submarine warfare operation, or giving the highest quality target position and forecast for weather over targets to a strike mission planner, the operational oceanography community is central to the success of the naval mission. Consistent with the concept of *"describ(ing) the organizing principles, operational concepts, and priorities by which future naval forces will exploit new opportunities and capabilities to assure U.S. access and influence forward in the Information Age"* (Navy Strategic Planning Guidance, 2000), the Oceanographer of the Navy (N096) recognizes the value of establishing a strategy for investment of research and development of resources to most effectively enable the warfighters of the future in the conduct of their missions.

To this end, our vision of operational oceanography is as follows:

Ensure our capability to deliver optimal knowledge of the maritime environment, for any concept of naval operations, anytime, anywhere.

… Where the following assumptions apply:

- Optimal = minimum required for greatest positive impact. This has implications for spatial and temporal resolution and accuracy as well as timeliness of delivery.
- Knowledge = characterization and forecast.
  - Characterization = data (measured and modeled) and decision aids.
  - Forecast = prediction in time and space, especially in the context of systems and weapons performance, mission planning, training, and acquisition.
- Maritime = open ocean and littoral.
- Environment = integrated battlespace (land, sea, air, space), parametrically defined and prioritized by relevance to operations.
- Operations = naval, joint, and combined.

II. Background - *Why do we believe we can get there?*

The operational utility of the products of research in oceanography has been demonstrated repeatedly, even as missions have changed dramatically. Operational oceanography has evolved as a function of several factors. A major driver of these changes has been the nature of the mission of U.S. naval forces. During the Cold War the focus of U.S. naval operations was in the open ocean, for anti-submarine warfare and deterrence. As a result, the focus of oceanographic research was on basin-scale and some mesoscale (i.e., tens of kilometers) physical oceanography, concentrating on studies of underwater acoustics (especially at low frequencies, detectable over large distances). We have recently capitalized on basic research done during the Cold War, with the development of the Modular Oceanographic Data Assimilation System (MODAS) to provide the fleet with improved acoustic prediction. MODAS starts with existing climatologies, assimilates data from *in situ* measurements such as expendable bathythermographs and remote sensing (satellite derived sea-surface heights and temperatures), and produces a three-dimensional, detailed depiction of the local thermohaline structure. For tactical purposes, this is then translated into highly accurate nowcasts of range-dependent acoustic propagation, accurately identifying sound channels, bottom bounce paths, and convergence zones (which would not be accurately depicted from just the climatology). This capability provides the fleet commanders a vastly improved capability for mission planning, operations and tactics.

With increased emphasis on littoral operations and power projection in recent years, research and development in operational oceanography has emphasized mesoscale meteorology, small-scale physical oceanography, non-acoustic technologies (e.g. optics, magnetics and radar), and high frequency acoustics. A particularly powerful product developed during this period is the Coupled Ocean-Atmosphere Mesoscale Prediction System (COAMPS), an operational model used to predict regional weather at high-resolution. The effectiveness of COAMPS was demonstrated repeatedly during the 1999 air campaign in the Kosovo crisis.

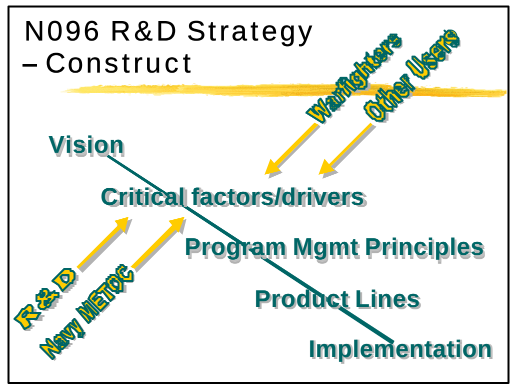
All of these operational products have a basis in navigation and geospatial information, requiring increasingly accurate measurements of time and time intervals. Modern navigation systems – for such ground-based systems as LORAN-C as well as for DOD's satellite-based NAVSTAR Global Positioning System (GPS) – depend on the availability and synchronization of a highly accurate clock. And in the communications and the intelligence fields, time synchronized activities are essential. The Oceanographer of the Navy, through the U.S. Naval Observatory (USNO), is charged with maintaining the DoD reference standard for Precise Time and Time Interval (PTTI). Through an aggressive program of research and development, USNO has developed the world's most accurate atomic clock system – the time and frequency standard for all of these systems. Thus, that clock system must be at least one step ahead of the demands made on its accuracy, and developments planned for the years ahead must be anticipated and supported.

In the near future (one to two decades) the naval mission will be characterized by several key trends (identified in more detail in section IV). All of these trends translate into specific needs for naval operations, each of which has obvious implications for operational oceanography. Forward presence and power projection are critically dependent on accurate predictions of environmental conditions over relatively long periods of time (many days to weeks) and for all regions (implying spatial scales of less than 10 kilometers) throughout the world. Similarly, recognizing that forecasts are only as accurate as the data used to initialize them, there is a need to characterize the battlespace environment over a wide area, at variable spatial and temporal scales, with minimal alert time. This means having the sensors, observational systems, and technologies for data assimilation in place for rapid environmental assessment. Once in theater, naval forces will be expected to navigate, target, deliver munitions, and conduct battle damage assessments as efficiently and quickly as possible. Highly resolved observations (implying extraordinarily precise timing and geospatial positioning) of weather, bathymetry and ocean conditions will be attained through the use of next-generation sensors and observational systems.

As a consequence of expected changes in naval operations and technical capabilities, there are specific challenges for the oceanographic community. First among these, perhaps most fundamentally, is the ability to develop fully integrated, seamless representations of the environment from below the seabed to beyond the upper atmosphere. Second is the challenge to build systems that are capable of fusing information and sampling in a sophisticated adaptive fashion. Third is the need to demonstrate knowledge superiority through the delivery of tactically important environmental knowledge (not just information) anywhere, anytime, in support of operations. And finally there is the challenge to design and accommodate architectures that allow straightforward "plug and play" capabilities for inserting new models and simulations.

The trends of oceanographic research as applied to naval operations have shown us that efficient transitions of science to applications depend on both operational 'pull' and technological 'push'. There are gaps in our future capabilities. Within the naval oceanographic community, these gaps must be filled with a concrete research and development strategy aimed at the vision defined above. The utility of such products as MODAS, COAMPS, and the USNO Master Clock clearly demonstrates the impact operational oceanography can have on the effectiveness of naval operations. This strategy will accelerate and improve the impact of operational oceanography for the warfighters of the U.S. naval forces.

III. Strategy – *What is the vehicle for getting there?*



The construct of this strategy is oriented towards the identification of specific product lines. Critical factors and drivers will force the vision identified above. By imposing strict principles of program management (which may include the introduction of new management processes) we expect to take the emerging products and implement them as aids to the warfighters, their systems, weapons and platforms, in a manner that is clearly assessable with established and newly-developed metrics.

This strategy will provide guidance and leadership for defining program planning and budgetary decisions in support of operational oceanography. It will provide the tools for identifying areas of focus for developing new capabilities. The guidance will invoke connectivity with programs of record and establish the routes for investment and disinvestment of research and development resources, as well as maintaining clear linkages and synchronization with Navy and Department of Defense planning and programming processes.

The goals of this strategy are manifold, and are shaped by its: 1) scope; 2) definition of customers; 3) definition of processes; 4) identification of deliverables, and 5) attention to metrics.

Scope

This strategy justifies a robust investment in oceanographic research and development. It serves as a tool in the development of program and budget defenses, for the future years defense plan (FYDP) and beyond. As such the strategy is unconstrained by the current Oceanographer of the Navy program, while maintaining consistency with and linkages to current processes. The strategy provides meaningful and 'living' guidance that is easily course-corrected as mission, technological capabilities, and organizational structures evolve. There is also consistency between this strategy and DoD, Navy, and other relevant policies and strategies. The scope of this strategy may also include the Oceanographer of the Navy research and development organizational structure and relationships (e.g. manning, requirements process, etc.)

Customers

The research and development strategy is sensitive to the needs and capabilities of a diverse and changing set of customers – operating forces of the fleet as well as the Naval Oceanography community. The strategy identifies the customer base through definition of product lines and processes. Support for this strategy also implies empowerment of the customer base.

Process

The improvement of existing processes and development of new processes are critical goals of this strategy. Such processes will provide a basis for making investment/disinvestment decisions. The emphasis on establishing "operational pull" early in the investment process – the 'buy-in' from the users – must be established up front. In this respect, the processes will serve to identify program strengths and weaknesses. It is also important that the processes be formulated in a manner to recognize and leverage a broad set of research and development opportunities, especially those within the private sector.

Deliverables

An essential goal of this strategy is the delivery of two specific products: 1) the means for prioritizing research and development investments and 2) the documentation to support the Oceanographer of the Navy research and development investment. The strategy should be lasting in its utility to provide these deliverables year after year.

Metrics

A collateral goal of the strategy is the development of a robust set of metrics for the Oceanographer of the Navy research and development investment. These metrics must allow evaluation of the research and development program in light of a wide range of considerations, including funding trends, transition rates from science and technology or into operations, support by other resource sponsors, and placement of operational oceanography resources, including personnel. The establishment of such appropriate metrics is the key to using this research and development strategy in program and budget defenses (see Section VI, Implementation).

In summary, this research and development strategy should be operationally based and oriented toward specific product lines. Priorities for investment will be keyed to anticipated operational oceanography-relevant factors and drivers in technology, mission, and organization; criteria for prioritization will be defined by clear and well-accepted metrics.

IV. Critical factors and drivers – *Why do we want to go there?*

The investment in research and development is guided by several critical factors and drivers. These serve to direct the investment in terms of defining the risk and facilitating the transition associated with a particular product line. The factors and drivers fall into several specific categories: mission orientation (including, more specifically, changes in the mission of operational oceanography); science and technology trends; and structural/organizational changes.

Key question: What are the expected changes in the nature of operations and warfighting?

Just as emerging capabilities in science and technology must drive the operational oceanography investment in research, we are guided by the direction of naval mission:

> *"The Naval Service exists to project U.S. power and influence from the sea throughout the spectrum of operations in peacetime, crisis and war. Forward presence and knowledge superiority are the* means *that will guarantee both the capability and the capacity of naval forces to influence, directly and decisively, events ashore. Concurrent battlespace control, attack, and sustainment are the* ways *we will assure the United States global access in the information age. Ultimately, the combat credibility of naval forces will guarantee the achievement of our* ends*: regional stability, deterrence, timely crisis response, and when called upon, warfighting and winning."* (Navy Strategic Planning Guidance, 2000)

Specifically, with the expected rise of regional actors, enhanced globalization and broadened spectrum of challenges to U.S. naval forces, we must be prepared for changes in potential adversary capabilities (e.g. the Office of Naval Intelligence assesses that our potential adversaries will continue to pursue area denial strategies over the next 15-20 years) and related concerns. Areas of specific interest include proliferation of theater ballistic missiles and weapons of mass destruction, reduced detectability of future submarines, increased anti-ship cruise missile capabilities, accelerating mine technologies, advances in surface to air missile capabilities, and signature reduction in surface ships. More generally, these issues impinge on naval oceanography in well-defined areas:

- **Asymmetric**: As we have already seen in recent conflicts, the asymmetry of weapons and targets will become an important aspect of systems design and platform protection. Drifting, moored, and buried mines, and weapons of mass destruction, incorporating highly sophisticated hardware and software, will be producible for only thousands or tens of thousands of dollars. But they will be capable of inflicting millions or tens of millions of dollars' worth of damage to surface ships, aircraft and submarines. Considerations of the environmental impact of these operations will be increasingly important.

- **Time-critical**: The conflicts of the future are apt to be similar in duration to recent hostilities in the Middle East and the Balkans. The pace of the war will be rapid, and in many cases, the termination of operations will depend critically on highly precise placement of munitions. Net-centricity, with its associated accelerated speed of command, will be an important factor.

- **Littoral**: Once again, recent engagements have demonstrated that naval operations will most likely be manifested as the extension of littoral warfare with projection of power farther inland (including military operations in urban terrain). Delivery of weapons, strike aircraft and ground forces will be from ships at sea, having global reach with requirements for access to denied areas.

- **Resource-optimized**: This means more than just saving money by being parsimonious procurers. This also suggests using more cost-efficient technologies for acquiring information, such as autonomous underwater and airborne vehicles. This also means exploiting capabilities for "just-in-time" logistics, applying modeling and simulation in training, acquisition and mission planning, where it is possible and where the models are robust.

- **Joint/Combined operations**: More planning and operations will be conducted on a multiforce and multinational basis, requiring interoperable command, control and communications. *"Power projection, enabled by overseas presence, will likely remain the fundamental strategic concept of our future force"* (Joint Vision 2020). This will be especially relevant for operations associated with trans-national issues such as natural hazard mitigation, anti-terrorism, and drug interdiction.

- **Knowledge superiority**: Information operations will play an increasingly important role. The ability to acquire, assimilate and apply tactically relevant environmental knowledge into decision-making systems (e.g. via sensor-to-weapon concepts) will prove invaluable. Space warfare and space control, associated with the operations of remote sensors will be fundamental aspects of operations. In support of knowledge superiority, the Navy Strategic Planning Guidance highlights two oceanography-related priorities for developing operational capabilities:

  – *Generating and disseminating precise time and time-interval signals to network nodes, critical to the calibration and operation of space-based systems for fleet precise geolocation, navigation systems, targeting, battle damage assessment, and communications.*

  – *The capability to organically measure and evaluate atmospheric, oceanic, and terrestrial battlespace environmental characteristics in real-time, essential for the operational decision-making and is a required input for sensor/weapons systems performance prediction and optimization as part of the common operational picture.*

Key question: What changes do we anticipate in the structure, manning, missions, and core competencies of operational oceanography that might impact a research and development strategy?

In the *1999 Strategic Plan of the Oceanographer of the Navy*, we see our future role encompassing a wide range of requirements including, but not necessarily limited to:

- Provide real time characterization and prediction of the battlespace environment – from the bottom of the ocean to the top of the atmosphere – in direct response to warfare requirements.

- Observe, analyze, forecast, and disseminate essential meteorological, oceanographic, and astronomical information at greater accuracy to improve sensor and weapon performance and ensure the safety of military personnel and equipment throughout the battlespace.

- Provide DoD with a robust global atmospheric numerical weather prediction capability – even at the mesoscale.

- Provide METOC sensor networks and ocean models that couple the ocean and atmosphere environments in littoral areas that are fundamental to naval forces maintaining information superiority.

- Develop numerical modeling and computational data analysis tools to process, analyze, and build products and services to satisfy validated requirements.

- Collect oceanographic data by shipboard and airborne surveys and remote sensing techniques, as supported in the CNO(N096) statement on "*The Importance of Ocean Observations to Naval*

Operations". In particular, high-resolution littoral oceanographic and atmospheric data are required to establish and maintain Sea Dominance and Power Projection superiority.

- Task and assimilate the collection of marine and bathymetric data, in accordance with high level priorities for production of maps, charts, and digital data products.

- Provide both precise atomic and astronomical time for DoD and related laboratories and agencies; determine and disseminate star positions and stellar references for approved navigation, guidance, and positioning systems; and accomplish research to meet future needs in the area of time and astrometry.

- Operate, maintain, and enhance the Precise Time and Time Interval core competency, by operating and developing near real time delivery of time interval and enhancing the prediction period of Earth orientation.

- Support an active research and development program integrated with an aggressive science and technology program in each of our core competencies; engage other resource sponsors to identify CNO (N096) programs for transition to their platforms.

- Maintain a vigorous and effective training program in all core competencies.

- Deliver naval oceanography information that is synchronized with the warfighter's decision loop through continued collaboration with warfighting Concepts of Operations (CONOPS). Similarly, deliver systems that are well integrated and linked with the Navy information technology architecture to ensure they provide valuable military capability.

Key question: What are the expected arenas of significant science and technology growth/opportunity?

While an important aspect of fundamental research is the unpredictability of discovery, there are important trends of investment from which we can expect significant new findings and capabilities toward which an operational oceanography research and development strategy should be geared[1]. The vision for the U.S. Navy in science and technology is to:

– Retain the historic connection to high quality world-class foundation research.

– Vertically integrate science and technology (6.1, 6.2, & 6.3).

– Move the Department of Navy science and technology program closer to the customer (warfighter).

– Bridge the gap between short-term needs and long term commitments.

To achieve this vision, the Navy focuses its environmental investment on: understanding ocean, atmosphere and air-sea processes; learning how to simulate and predict those processes; assessing the effect of processes on

[1] *By the same token, it is important to recognize that diligence to progress in science and technology can also be used to identify when to defer more advanced research and development investments, to await the emergence of a new technology: i.e. a 'techno-pause'*

operations, people, sensors and systems; and developing concepts for rapid characterization and adaptation. Over the next 15 years, the thrusts and technical challenges in science and technology are identified as:

- Predictive Systems
    - develop ocean and atmospheric observations and models that provide a predictive ability to the on-scene commander, with special emphasis on the littoral zone
    - develop advanced wave prediction methods and radiative transfer models for visibility in the ocean and atmosphere
- Large Scale Processes
    - develop understanding/characterization of the large scale processes in the ocean and atmosphere that control the overall setting in which most naval operations occur
- Small Scale Processes
    - develop understanding/characterization of small scale processes that affect systems (acoustic, optical, electromagnetic/electro-optic, gravity and magnetic)
    - coastal hydrodynamic processes and fluid/structure interactions
- Sensors/Data
    - atmospheric and oceanic observations at high resolution in denied areas
- Quantify Role of Environment on Systems (jointly)
    - determine for all warfare areas the most critical environmental data
    - quantify impact of environmental data in all warfare areas

In the longer term, the science and technology investment is oriented toward a grand challenge of Environmental Dominance, characterized by elements such as: providing maritime intelligence, surveillance & reconnaissance (ISR) on demand; fielding environmentally adaptive systems; "owning the Environment" through superior knowledge of the current and future environment, including effects on systems and tactics; establishing a subsea littoral adaptive presence that can be monitored & controlled remotely (networked autonomous systems); having an expanded engagement envelope (i.e. submarine detection and classification distances that are twice the range of torpedoes); developing real-time techniques to accurately fuse and display multi-source data in common frames of reference; and assuring unimpeded movement from sea to shore with amphibious assaults at full operational tempo in all environments.

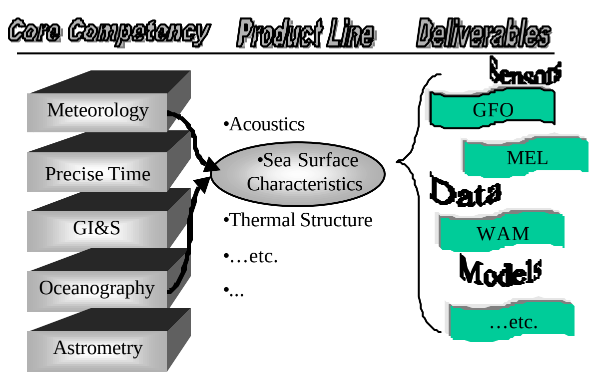
The N096 research and development strategy is focussed on defining the direction for future investments. An understanding of the critical factors and drivers is needed to help set the best course for these investments. Therefore, the answer to the question posed earlier, *"Why do we want to go there?"* comes from the combined consideration that science and technology and organizational trends suggest we *CAN* go in a particular direction, and mission orientation suggests we *SHOULD* go there.

V. New directions – *What products do we need to get there (in terms of how we manage research and development, and what research and development produces)?*

<u>Product lines</u>

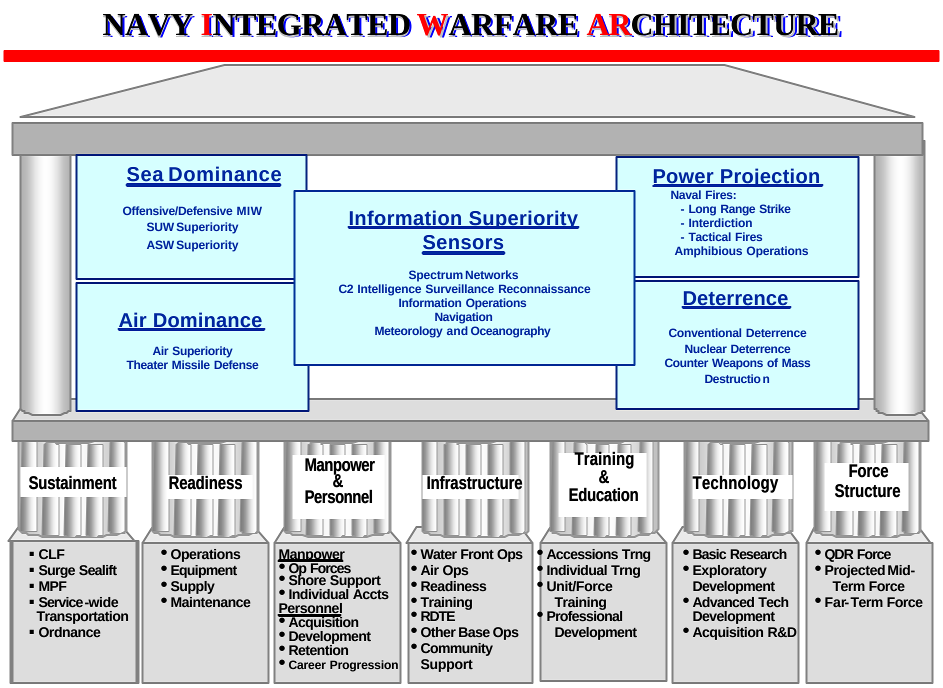
The key element of this strategy for research and development is the definition of operational oceanography product lines that transcend missions. Product lines are defined at a level of specificity finer than that of a program element or core competency, but coarser than that of a project or task. Product lines are durable, and their lasting nature is characterized by an evolution of the components within that line. These product lines also tend to be unique to the operational oceanography community. A product line is not prescribed in terms of resource allocation (i.e. minimum or maximum budget allocation) or class of components (e.g. exclusively sensors or models). Instead, the product line is defined as the area of research and development specific to the transition of capabilities to meet the requirements of the warfighters and operators.

As an example, consider one operational oceanography product line in support of a mine countermeasures mission. The broad naval oceanography core competency of immediate relevance is oceanography, while a very specific component transitioned in support of tactical decision-making is the wave-forecasting tool, WAve Model (WAM). This tool may be used to support a variety of tactics, from mine-hunter search track designation to GO/NO GO decisions on the use of airborne LIDARs. Within this same naval oceanography core competency (oceanography), however, there are families of additional specific components, useful for tactical decisions, such as satellite altimetry for near real-time synoptic imagery of the sea surface in the theater, or climatological databases of seasonal sea state for the region. Each of these components represents a project, or specific investment within a **product line** that could be defined as "***Sea surface characteristics***". This product line, then, contains a range of projects, including models, databases, and sensors. The product line is more specific than the broadly defined core competency of "oceanography", and transcends a range of missions; the product line of "***Sea surface characteristics***", cited above, with, perhaps, a different mix of projects, would also apply to an amphibious warfare mission, or a logistics over the shore mission. Conceptually, then, the taxonomy of product lines is as shown graphically as:



Product lines are enduring elements of this research and development strategy. Their general definition remains unchanged over time, while their specific orientations will evolve to fit changing naval operations. The product line cited in the example above is not new, but the specific elements do represent the leading edge in environmental research and development. An important component of this strategy, therefore, is the definition of product lines, in terms specific to projects or systems. Appendix A provides a comprehensive characterization of the product lines meeting the criteria identified above. The implementation of this strategy must include a regular and careful consideration of these product lines, in terms of their composition and their evolution.

As science and technology advances and the operational mission changes, new product lines may be introduced. Therefore, product lines must be adaptable to the current mission taxonomy. To ensure successful implementation, this strategy must define product lines in the context of the US Navy's Integrated Warfare Architecture (IWAR):



The Navy operational oceanography research and development program is an integral component of this architecture, for a range of domains and sub-domains. The priority for investment must be driven by a spectrum of criteria, imposing those values most relevant to the performance of the warfighters and their systems. The specific criteria for consideration of product lines are as follows:

- Warfighting value (not prioritized) – What product lines are important to warfighting?

- Innovation/Improvement over current capabilities (prioritized) – Which product lines will yield new or improved capabilities at any/all levels of performance, from the individual through the battle group, to service-wide?

- Urgency (prioritized) – In which product lines are improvements needed now? Will a delay in fielding a capability adversely impact the warfighter?

- Risk (prioritized) – Based on established concepts of operations and definitions of operational assumptions, which product lines will a research and development investment yield an acceptable product at cost and on schedule?

- Alternative research and development source (prioritized) – For which product lines might a modest Navy investment ‘leverage’ research that is being supported elsewhere?

- Meets multiple capabilities (prioritized) – In which product lines will an investment provide identifiable improvements for other missions?

Given these criteria, and the spectrum of IWAR domains and subdomains, the product lines for operational oceanography research and development investment can be characterized in a portfolio of decision matrices, an example of which might be as follows:

SAMPLE

R&D Product Lines

Domain/Subdomain \ *Criteria*	Warfighting value	Innovation/Improvement (Hi to Lo)	Urgency (Hi to Lo)	Risk (Lo to Hi)	Alternative R&D sources (Many to Some)	Multiple missions (Many to Some)
Sea Dominance						
ASW Superiority	Ac	NonA	Ac	SBC	SBC	SBC
	NonA	Ac	NonA	Wx	Wx	Wx
	NAV	SBC	SBC	NAV	SSC	NAV
	SBC	EM/EO	NAV	Ac	OD	Ac
	SSC	NAV	EM/EO	SSC	NAV	SSC
	Wx	Wx	OD	OD	NonA	OD
	EM/EO	OD	SSC	EM/EO		EM/EO
	OD	SSC	Wx	NonA		NonA
Power Projection						
Strike	PT	PT	Wx	PT	Wx	Wx
	Wx	Wx	PT	NAV	PT	PT
	EM/EO	EM/EO	NAV	EM/EO	NAV	NAV
	NAV	NAV	EM/EO	Wx		EM/EO

Ac = Acoustics
EM/EO = Electromagnetics/Electro-optics (in atmosphere)
NAV = Navigation
NonA = Non-acoustics (in water)
OD = Ocean dynamics
PT = Precise time
SBC = Sea bed and terrain characterization
SSC = Sea surface characterization
Wx = Weather

Product lines are the enduring elements of this research and development strategy that, by being equally interpretable by the warfighter, research, and METOC communities, provide long term linkage between our CNO(N096) R&D investments and Navy missions.

VI. Implementation - *How do we get there*?

First and foremost in the implementation of this strategy is the need for establishing a regular review of investment plans in conjunction with the product line alignment defined above. This will be done on an annual basis, and in a manner consistent with current attention to operational requirements and mission needs. Such an assessment will be coordinated by the Office of the Oceanographer of the Navy, with the required participation by all of his claimant commands, and with the invited participation of all recognized stakeholders (i.e. S&T community and users of METOC products). The most current assessment shall be published by N096 and forwarded to all stakeholders as guidance.

All operational oceanographic research and development will be undertaken in the context of battlespace meteorology and oceanography (METOC) data acquisition, assimilation, and application (BMDA[3]). Acquisition means both sensing of data as well as 'finding' (i.e. accessing) them through optimized database management. Assimilation includes the ingest and upgrade of data into models and simulations, as well as the representation of the output through advanced visualization techniques. Application of the data will be for two fundamental functions: prediction of system performance as a result of environmental variability, and decision-support regarding tactics that are affected by the environment.

The following principles will be applied to construction and maintenance of the operational oceanography research and development portfolio:

Competition and peer review

All projects supported within product line definition will be reviewed using existing forums, including, but not limited to sponsor's program reviews, research and development reviews, POM cycle, PPBS, IWARS Focus Area assessments, CINC 'Top 10' discussions and FNC reviews. The Oceanographer of the Navy will also institute new processes for the review and support of jointly proposed 6.1-6.4 projects with the Office of Naval Research (e.g. a Rapid Transition Process). Reviews will include rigorous assessments of technical, programmatic and operational suitability of proposed efforts, to include extensive fleet feedback and consideration of interagency opportunities. Most notably, all program reviews and planning efforts must be consistent with the product line-based assessments emerging from this strategy. These reviews may result in identification of needed sensitivity studies prior to investment in particular research areas.

Metrics

Well-understood and established metrics must be invoked in all assessments. Metrics will be applied at several levels: for the overall R&D investment, at a project-specific level, and by product lines. Mission sensitivity studies will be imposed to assess impact of research investments. The technical merit of potential projects will be evaluated in terms of the validity of the science and technology foundation upon which further research and development will be based, with a technically sound path identified for transitioning to operations. Standard metrics will also be applied in estimating the anticipated benefit to the warfighter of each investment, articulated in terms understandable by the warfighter and, whenever possible, mapped to platform and mission-relevant measures of effectiveness. Similar metrics will be applied to routinely evaluate the overall effectiveness of the operational oceanography research and development strategy.

Definition of exit criteria, plans of action and milestones

Prior to all research and development investments, the proposed efforts must be well defined, in terms of when products will become available for initial and final operational evaluation. Decision points must be well identified, along with reasonable metrics for along-course assessment of progress toward stated objectives. It may be appropriate to identify target capabilities that transcend product lines, and use these targets as critical components in assessment of progress within individual projects.

Affordability

In assessing the suitability of research investments the impact of costs must be weighed. The affordability of investment, including total ownership costs, cannot be considered absent the expected gain or benefit. Recognizing the associated errors in cost estimation, an affordability "figure of merit" must be defined and applied as a fundamental principle in the construct of the research portfolio. Standards of 'realism' of costs should also be well defined in order to assess, objectively, the relative affordability of competing proposals within a particular product line. The assessment of total ownership costs should invoke consideration of appropriate opportunities for cost sharing or leveraging of related investments. Additionally, to enhance affordability, the National Oceanographic Partnership Program will continue to be utilized, to leverage relevant investments by other Federal agencies.

VII. Summary

The US Navy operational oceanography research and development investment is a powerful tool for taking the leading edge capabilities and applying them to the operational requirements in a manner most beneficial to the warfighter. This strategy focuses on developing a structure for R&D programming, planning and budgeting. By successfully applying the mechanisms defined herein, the METOC community can prioritize and defend our investments in terms that are most useful for a broad range of interested customers, from the operational community to the scientific community.

Product lines, defined in terms of operational impact and assessed using mission-oriented criteria, provide the currency for this R&D strategy. Their evolution and impact will be determined with a clear set of metrics and within a well-defined set of review forums. With regular attention to the mechanics defined in this strategy, the METOC R&D community will build an increasingly effective suite of products to successfully transition to operational fleet use.

REFERENCES

a. "*The Importance of Ocean Observations to Naval Operations*", 1999 (CNO(N096) memorandum Ser 096T/9U570840).
b. *Strategic Plan of the Oceanographer of the Navy*, CNO(N096), 1999.
c. *Navy Strategic Planning Guidance*, Department of the Navy, 2000.
d. *Joint Vision 2020*, Joint Chiefs of Staff, 2000.

APPENDIX A. PRODUCT LINES

Defined broadly, the naval oceanography product lines include the following types of projects:

1. **Atmospheric Electro-Magnetic/Electro-Optical Propagation (EM/EO)**: atmospheric temperature, moisture, and aerosols as they affect sensors and weapons systems operating in the optical and electro-magnetic spectrums.

2. **Geodesy (Geod)**: determination of the shape of the earth and exact positions on the earth's surface, including gravity and magnetic variations in the oceans.

3. **Navigation (Nav)**: efforts directed at ensuring the safe movement of aircraft, vessels, and forces through and above the maritime and littoral environment. Primary interest area is in the development of bathymetric charts (electronic and paper). This product line also includes astrometry, the precise determination of the position and motion of the sun, moon, stars, and planets for use in navigation and guidance systems.

4. **Ocean Acoustics (OAc)**: ocean characteristics that affect the propagation of sound through the ocean – primarily temperature, salinity, and ambient noise – created at the ocean surface by weather (winds, waves, precipitation), and by sea ice movement, marine life activity, etc.

5. **Ocean Dynamics (OD)**: tides, surface and sub-surface currents and internal waves produced as a consequence of various force interactions in the ocean.

6. **Ocean Non-Acoustics (ONonAc)**: physical, chemical and biological properties of the ocean (*e.g.* ocean clarity, bioluminescence, etc.) that impact the transmission of electromagnetic radiation in the ocean (primarily visible wavelengths – *e.g.* LIDARs), or are detectable using means other than acoustic.

7. **Precise Time (PT)**: maintaining the nation's precision time and time interval references.

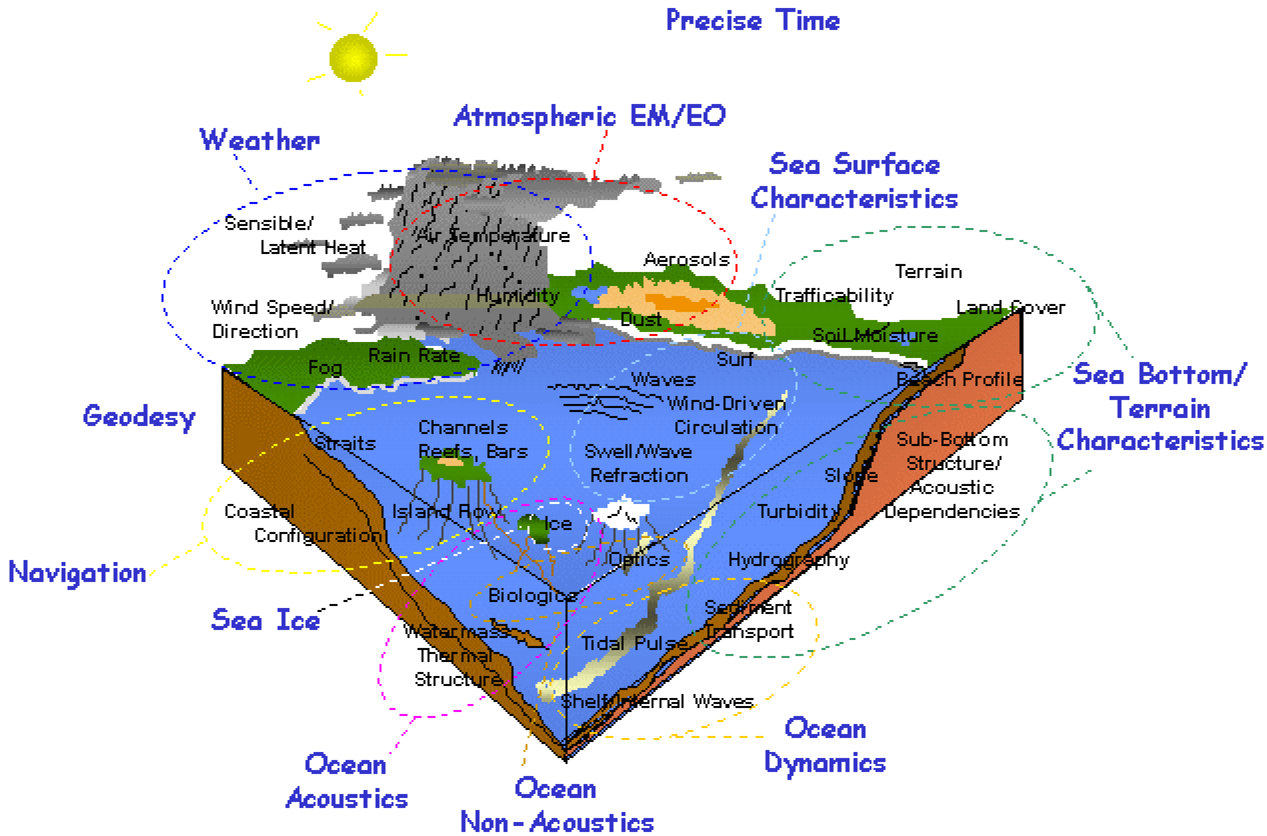
8. **Sea Bottom and Terrain Characteristics (SBTC)**: bathymetry, sea floor and sub-sea floor composition, littoral topography, and ground trafficability as they affect the full spectrum of sub-surface, surface, aviation, and ground operations.

9. **Sea Surface Characteristics (SSC)**: results of the interaction of the ocean with air and land boundaries, such as wave and swell height and direction; surf and breaker height, direction, and type; and wave and current diffraction.

10. **Sea Ice (Ice)**: analysis and prediction of sea ice coverage and thickness, primarily in polar regions, but also in straits, bays, etc. as required.

11. **Weather (Wx)**: atmospheric phenomena as they affect naval operations (other than EM/EO). This broad product line includes a variety of interrelated parameters such as air temperature, moisture, cloud cover, visibility, wind, obstructions to visibility, precipitation, etc.

The depiction below illustrates the relationship between these product lines and the data we routinely collect in developing our operational naval METOC products and services:



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